Diagnostics

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NCSX Program Advisory Committee Meeting #7

Princeton Plasma Physics Laboratory

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Outline

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- Diagnostic implementation phased to meet needs of research plan
- Ports optimized for good diagnostic access
- Port map with diagnostics port assignments
- Diagnostic concepts used to guide port design
- Responses to PAC-6 recommendations
- Plan for diagnostics participation

Diagnostics phased to research plan

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DIAGNOSTIC	DESCRIPTION	FY4	5	6	7	8	9	10	11	12
diagnostic integration										
1. Field Line Mapping to Check Machine Assembly (B=0.5 T, room temperature)										
e-beam mapping	e-gun on probe, fluor. wire array									
ex-vessel magnetics	200 ext. sensors & few integ.									
2. Initial Plasma Operation and Cold Field Line Mapping (B=0.5 T, cryogenics)										
visible cameras	1 fast cam.+shield on beam port									
3. 1.5 MW Initial Experiments (1.5 MW NBI, B=1.2 T, partial PFCs)										
in-vessel magnetics	100 B_r coils+100 integrators									
2 filtered cameras	2 add'l cam in reent., shut. assy									
core Thomson scattering	partial detector array, 100 Hz									
core FIR interf./ polarim.	partial detector array									
x-ray crystal spectrometer	imaging sys. with 2-D detector									
compact SXR arrays	8 arrays of 20 channels									
wide angle bolometer	4 channels in wide angle view									
visible spectrometer	multichan., survey instrument									
abs. UV spectroscopy	vac. UV survey instrument									
compact IR camera	no periscope, standard speed									
plate mount Langmuir probes	array of fixed probes									
fast neutral pressure gauges	midplane and banana tips									
moveable Langmuir probe	moveable between shots									
visible filterscopes	several sightlines									

In construction project

Blue: key diagnostics

Diagnostic implementation-continued

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4. 3 MW Heating (3 MW NBI, full PFCs, B=2.0 T, 350 C bake)		FY4	5	6	7	8	9	10	11	12
additional magnetics	add 50 varied sensors & integ.									
Thomson profile system	60 spatial channels, 100 Hz									
FIR interf./ polarim. profile	full array of detectors									
filtered 1D CCD camera	single view									
core foil bolometer array	12 add'l channels (16 total)									
diagnostic neutral beam	50 kV, 6 amps neutrals, 6 cm									
MSE polarimeter	uses DNB, midplane view									
toroidal CHERS	uses DNB, midplane view									
enhanced x-ray tomography	additional 8 compact SXR arrays									
poloidal CHERS	uses DNB, vertical view									
fast tang. x-ray camera	uses unused beam port									
fast ion loss probe	geometry TBD									
neutral particle analyser	legacy analyzer (PLT or NSTX)									
epithermal neutron detector										
high frequency Mirnov coils	12 larger TFTR style coils									
5. Confinement & β push (3 MW NBI & 6 MW NBI or RF, divertor)										
divertor foil bol. arrays	2 crossed, 16 channel arrays									
divertor filtered CCD camera	view TBD									
fast IR camera	needs periscope									
fast scanning edge probe	geometry TBD									
He CHERS system	uses DNB									
divertor thermocouples	instrumented divertor tiles									
divertor UV spectroscopy	dedicated divertor view									
fluctuation diagnostic	TBD									
6. Long pulse (Existing heating & 3 MW long pulse NBI or RF)		FY4	5	6	7	8	9	10	11	12
divertor Thomson scattering	100 hz, 20 spatial channels									

Blue: key diagnostics

Ports optimized to provide good access

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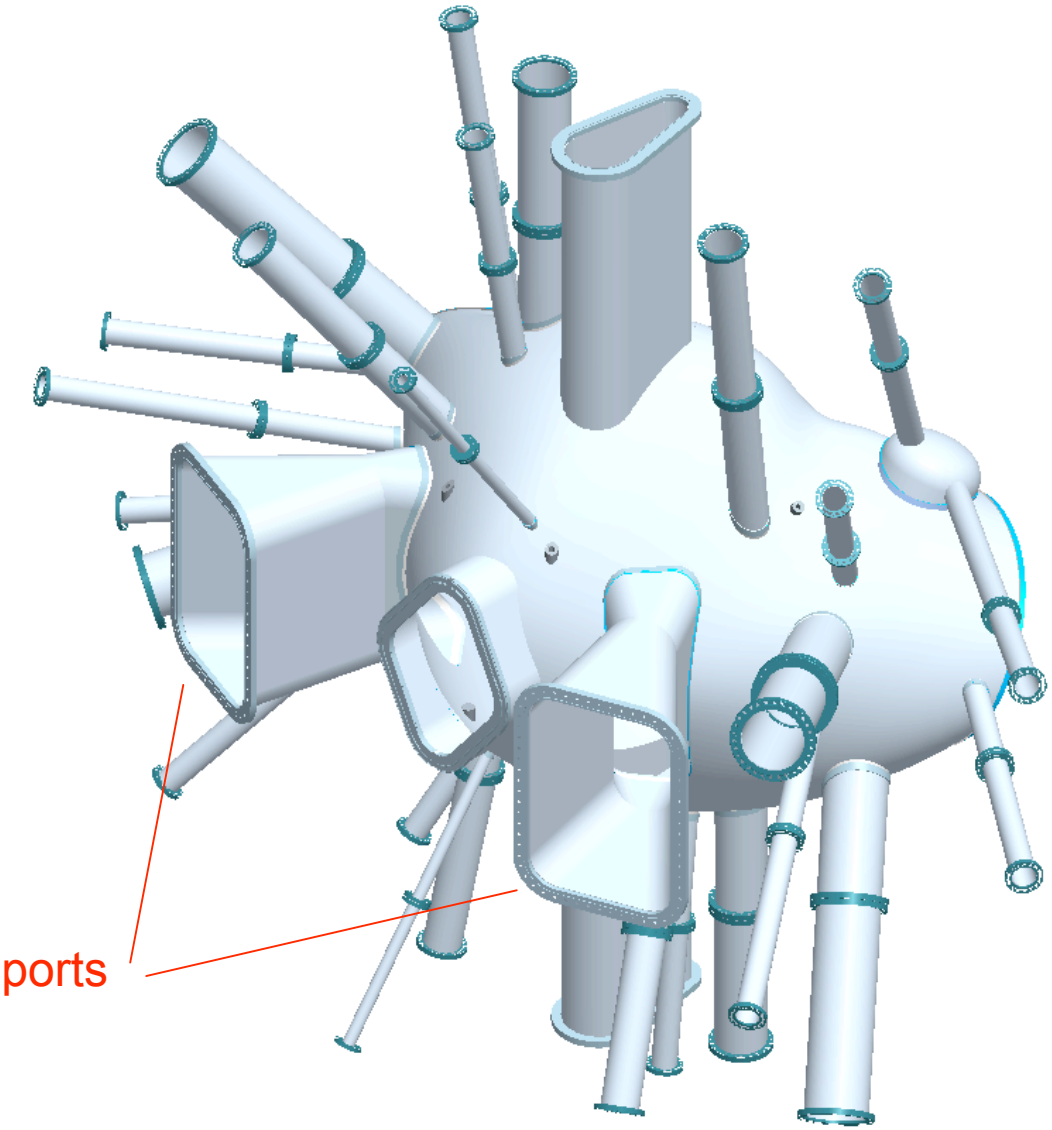

Preliminary diagnostic port assignments

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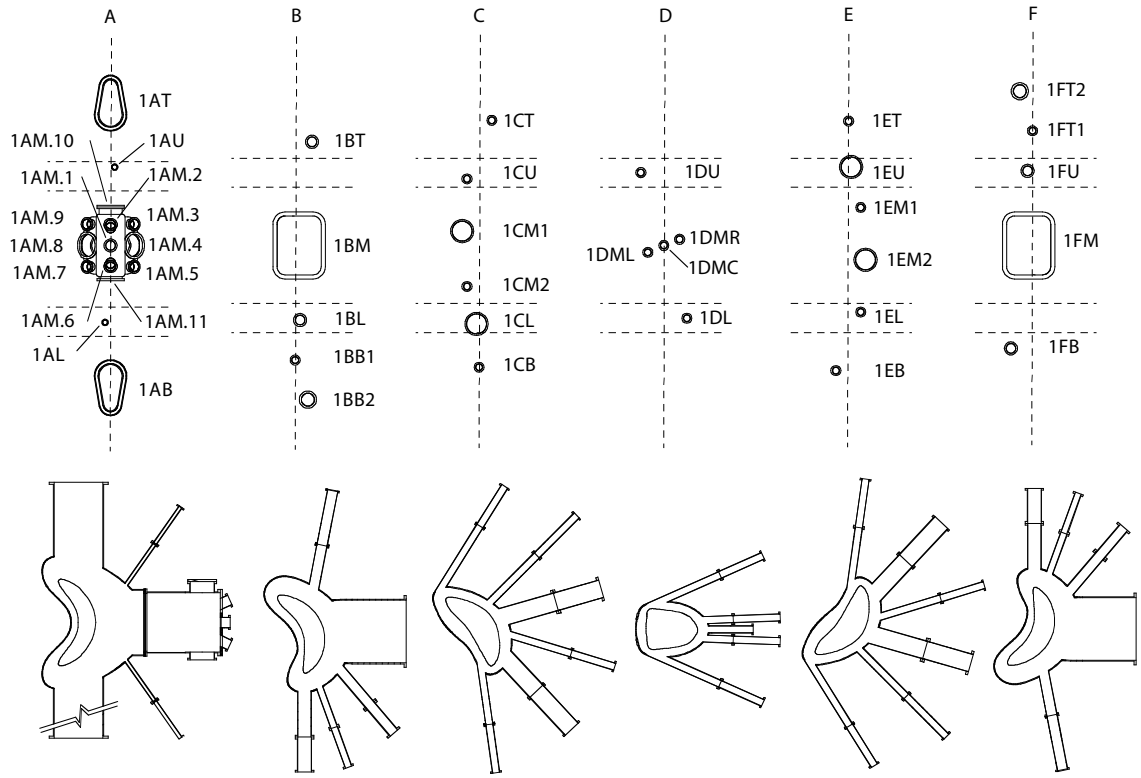
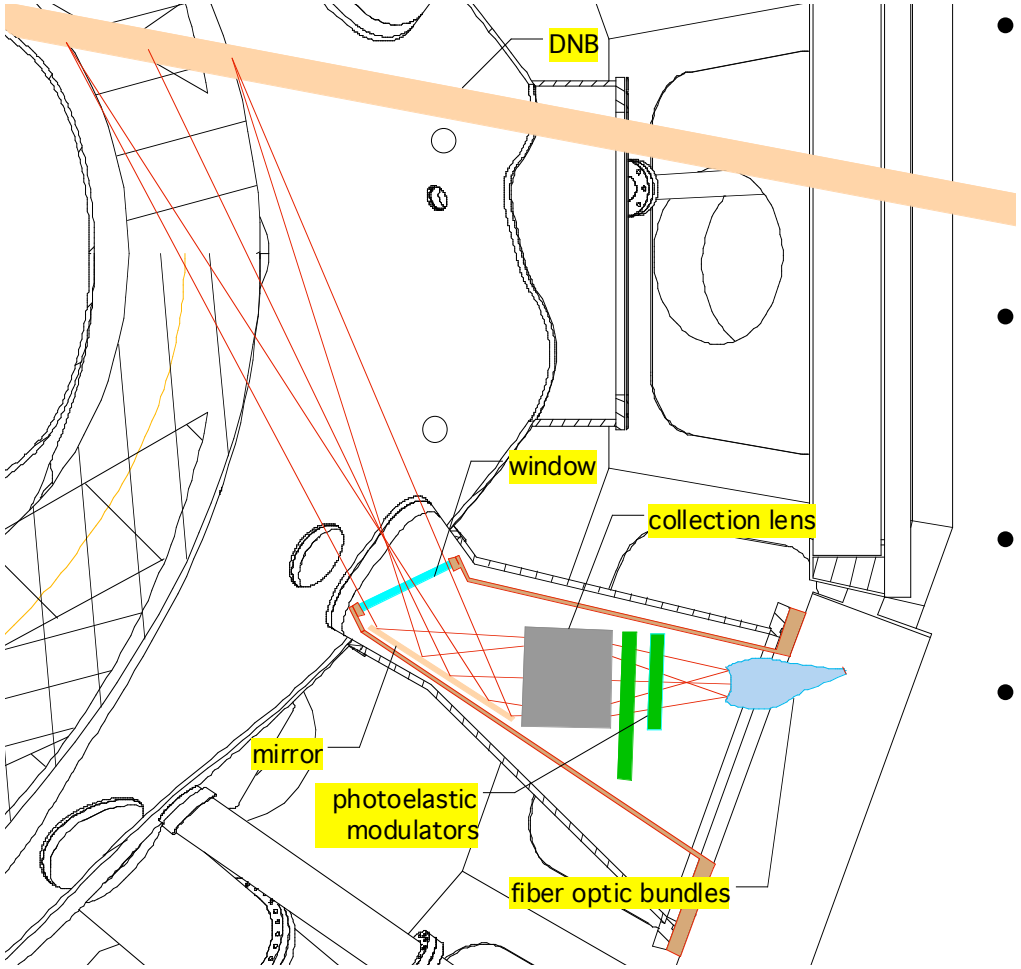
Example: Period 1

Complete port map in appendix



A			B	C	D	E	F
	1AT div. bolometer div. camera		1BT	1CT		1ET equilib. magn. (120 MI)	1FT2 inboard gas or pellet inj.
	1AU				1DU Mirnov coils (90 tp)		1FT1
	1AM.10			1CU		1EU gas inj. (reg. & supersonic)	1FU Mirnov (20 tp) thermo (15 tp)
1AM.9 thermocouples (45 tp)	1AM.2	1AM.3 ion gauge		1CM1	1DMR SXR arrays (90 tp)	1EM1	
1AM.8 heating neutral beam	1AM.1 1 mm interferometer	1AM.4 heating neutral beam	1BM fluctuation diag. (BES)		1DMC SXR arrays (90 tp)	1EM2 1-D filtered (Hα, C) camera	1FM CHERS/MSE & He CHERS
1AM.7 fast pressure gauges	1AM.6 divertor UV spectrometer	1AM.5		1CM2	1DML SXR arrays (90 tp)		
	1AM.11 vacuum pump, ion gauge		1BL core UV spectroscopy	1CL visible spectroscopy		1EL	
	1AL		1BB1		1DL fast pressure gauges		1FB
	1AB div. Bolometer div. IR camera		1BB2 glow probe & 2 filaments (5 c)	1CB equilib. magn. (120 MI)		1EB	

Active spectroscopy uses flared port



- Diagnostic neutral beam required to obtain good spatial resolution for CHERS and MSE.
- Viewing a DNB as shown provides optimum spatial resolution.
- CHERS and MSE share light collection optics.
- There are six flared ports on the vessel.

Multi-channel FIR interferometer/polarimeter

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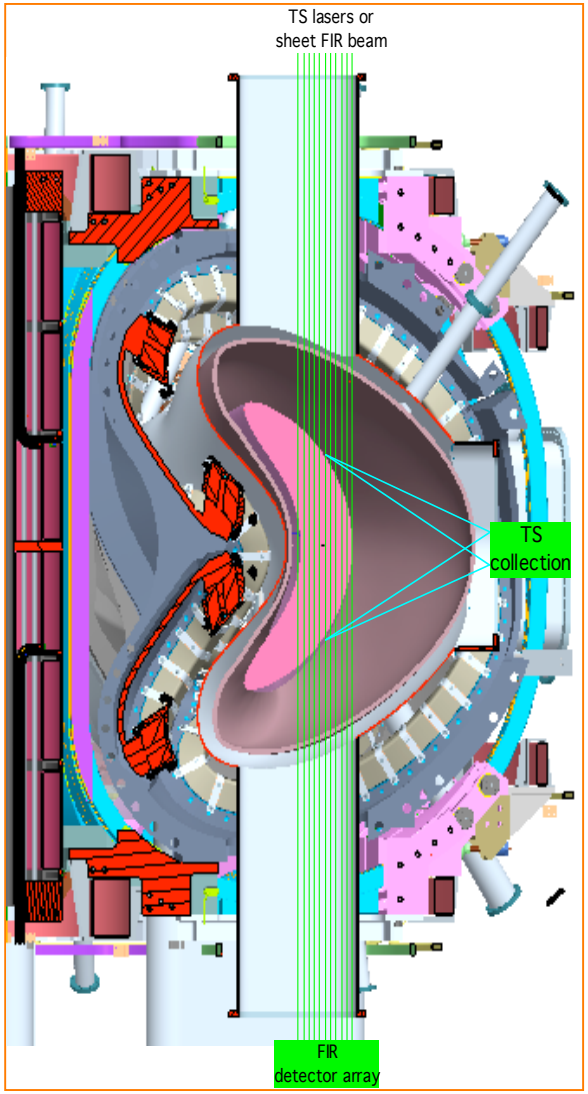
- Measures $n_e(R)$, $j(R)$, and $B_p(R)$ fluctuations.
- Uses radially elongated top and bottom ports at the v=0 symmetry plane.
- Vertical sheet laser beam
- Achieves 1.0 - 1.5 cm radial channel spacing with 20 - 30 channels.
- Concept for Thomson Scattering optics viewing vertical laser beam also shown



Challenging space constraints for soft x-ray arrays

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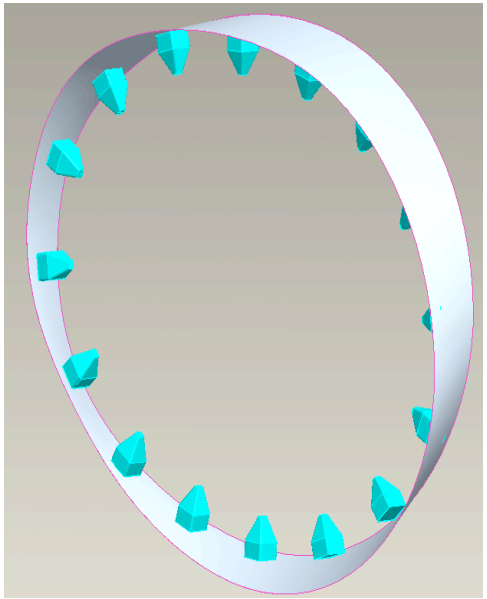

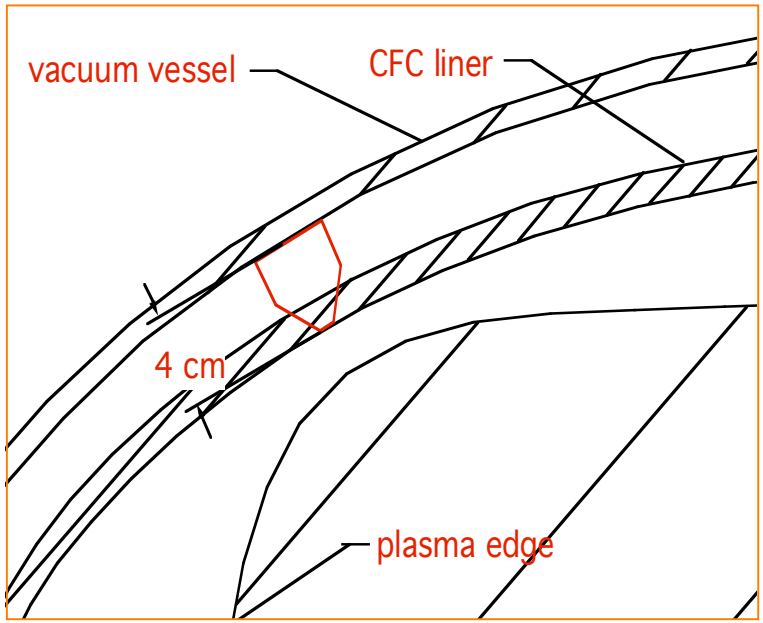

- To achieve adequate spatial coverage for tomography, soft x-ray arrays will be installed between first wall and vacuum vessel to view oblate plasma cross section
- Integrate arrays into vacuum vessel spacer flanges
- Radial space constraint as small as 4 cm requires compact design

Responses to PAC-6 recommendations-1

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- Ports optimized for diagnostic access
  - Number, size and orientation of ports improved
  - Flared ports
- 3-D diagnostics:
  - Magnetics sensors will provide input for 3-D equilibrium reconstruction
  - Development of new 3-D diagnostics will be encouraged in research forum and calls for proposals
- Conceptual design of external magnetics sensors compatible with vessel design and machine assembly
- Extensive set of edge/divertor diagnostics planned
  - See P. Mioduszewski's talk on plasma boundary research

Responses to PAC-6 recommendations-2

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- A fluctuation diagnostic is planned for phase 5
  - Technique to be determined: HIBP, BES, reflectometry, microwave scattering are candidates
  - Excellent access to vertically elongated cross-section
- Extensive metrology planned
  - Will be used to determine locations of diagnostics systems

Plan for diagnostics participation

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- Significant university/industry participation planned for phase 3-6 diagnostics, similar to NSTX
- First call for diagnostic proposals in FY06, for funding starting in FY06/07
- Additional calls for proposals in FY07 and FY08
- Basic and profile diagnostics required for research program phases 3 and 4 to be installed in late 2008 and mid-2009

Plan-continued

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- Diagnostic design/fabrication must start 1-2 years before installation to meet schedule
- Need to start assembling diagnostics team
- First NCSX Research Forum in Spring 2005 will provide opportunity to continue recruiting diagnosticians
- Aim to identify candidate diagnosticians needed for phase 3 and 4 diagnostics by end of FY05

Appendix: complete port map

Port map: period 1

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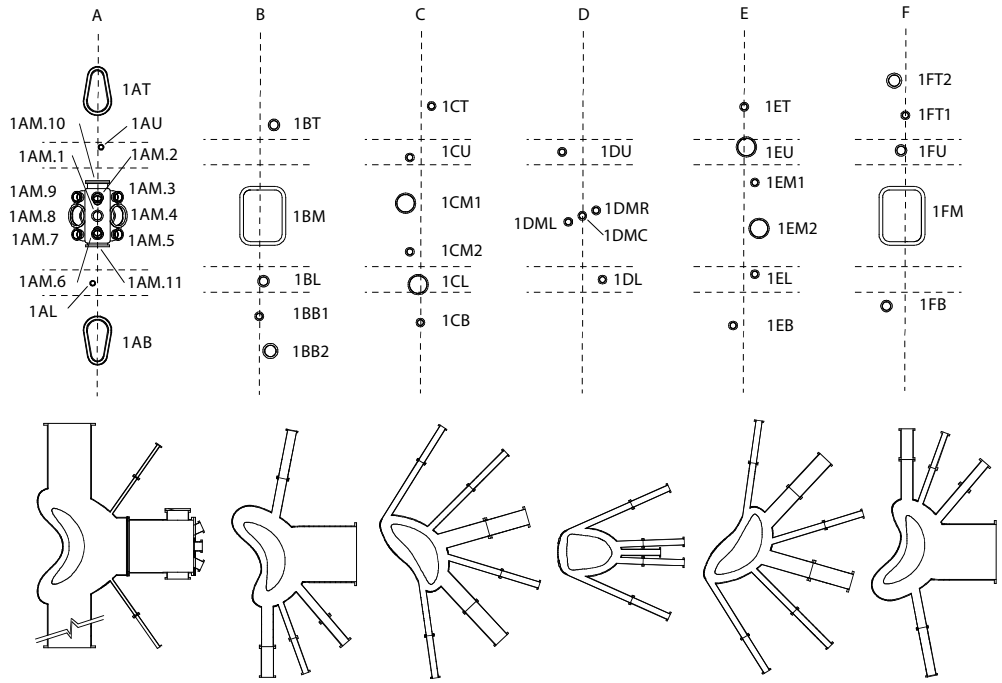

A			B	C	D	E	F
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	1AM.10			1CU		1EU gas inj. (reg. & supersonic)	1FU Mirnov (20 tp) thermo (15 tp)
1AM.9 thermocouples (45 tp)	1AM.2	1AM.3 ion gauge		1CM1	1DMR SXR arrays (90 tp)	1EM1	
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1AM.7 fast pressure gauges	1AM.6 divertor UV spectrometer	1AM.5		1CM2	1DML SXR arrays (90 tp)		
	1AM.11 vacuum pump, ion gauge		1BL core UV spectroscopy	1CL visible spectroscopy		1EL	
	1AL		1BB1		1DL fast pressure gauges		1FB
	1AB div. Bolometer div. IR camera		1BB2 glow probe & 2 filaments (5 c)	1CB equilib. magn. (120 MI)		1EB	

Electrical feedthroughs: tp=twisted pair, MI=mineral insulated cable, c= single conductor

Port map: period 2

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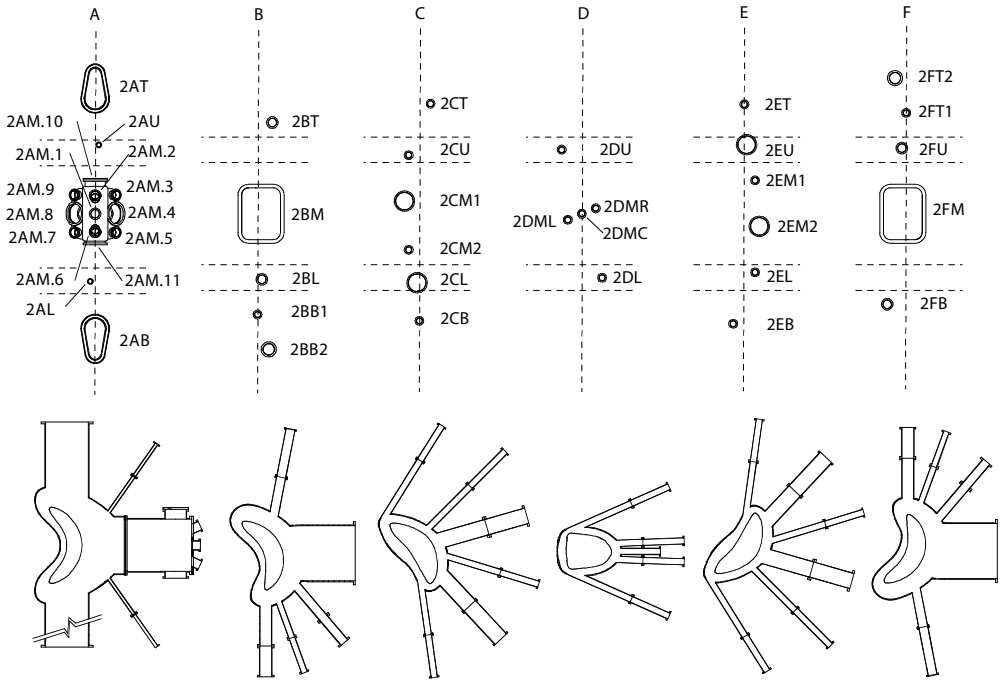

A				B	C	D	E	F
	2AT MPTS dump, divertor TS			2BT	1CT		2ET equilib. magn. (120 MI)	2FT2 inboard gas or pell. Inj.
	2AU					2DU Mirnov coils (90 tp)		2FT1 HIBP?
	2AM.10				1CU		2EU gas inj. (reg. & supersonic)	2FU Mirnov coils (20 tp)
2AM.9 thermocouples (15 tp)	2AM.2 visible filterscope	2AM.3 ion gauge			2CM1 e-beam mapping probe	2DMR SXR arrays (90 tp)	2EM1	
2AM.8 visible camera	2AM.1 diagnostic neutral beam	2AM.4 visible camera		2BM MPTS view		2DMC SXR arrays (90 tp)	2EM2 visible filterscopes	2FM fluctuation diag. (HIBP?)
2AM.7 fast pressure gauges	2AM.6 visible filterscopes	2AM.5 divertor visible camera			2CM2	2DML SXR arrays (90 tp)		
	2AM.11 vacuum pump, ion gauge			2BL core bolometer	2CL fast scanning edge probe		2EL	
	2AL			2BB1		2DL fast pressure gauges		2FB
	2AB MPTS laser, divertor TS			2BB2 glow probe & 2 filaments (5 c)	2CB equilib. magn. (120 MI)		2EB	

Electrical feedthroughs: tp=twisted pair, MI=mineral insulated cable, c= single conductor

Port map: period 3

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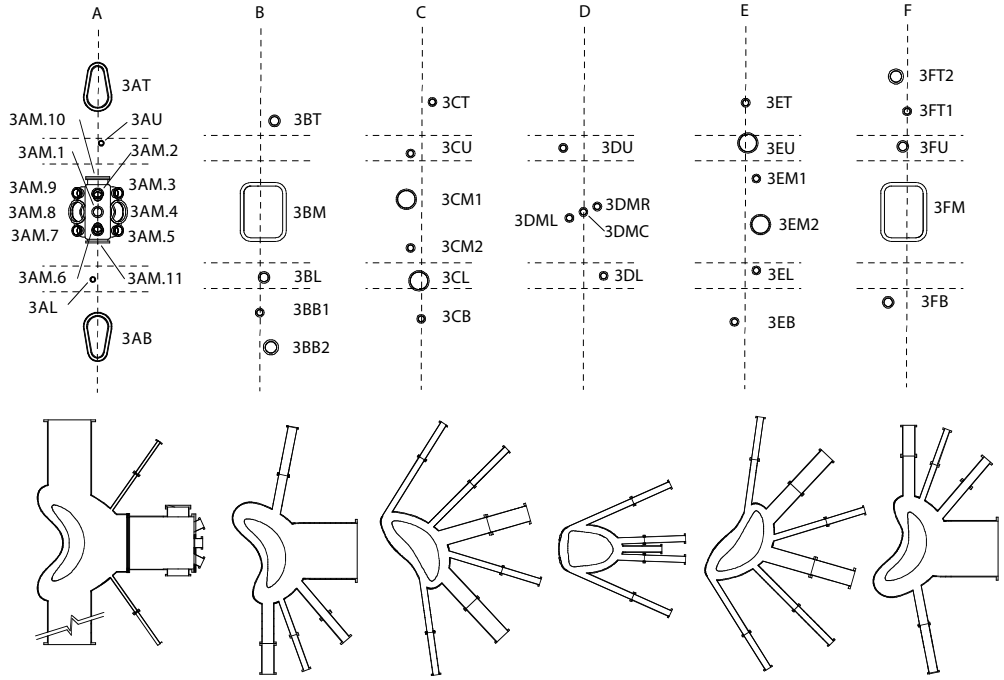

A					B	C	D	E	F
	3AT	FIR interf./polarim.			3BT	3CT		3ET equilib. magn. (120 MI)	3FT2 inboard gas or pellet inj.
	3AU						1DU Mirnov (90 tp) thermo. (30 tp)		3FT1
	31M.10					3CU		3EU gas inj. (reg. & supersonic)	3FU Mirnov coils (20 tp)
3AM.9 thermo. (15 tp) Lang. Pr. (50 c)	3M.2		3AM.3 fast IR camera			3CM1	1DMR SXR arrays (90 tp)	3EM1	
3AM.8 visible camera	3AM.1	X-ray crystal spectrometer	3AM.4 fast tang. X-ray camera		3BM neutral particle analyzer		1DMC SXR arrays (90 tp)	3EM2 fluctuation diagnostic	3FM e-beam mapping target
3AM.7 fast pressure gauges	3AM.6	X-ray crystal spectrometer	3AM.5 ion gauge			3CM2	1DML SXR arrays (90 tp)		
	3AM.11	vacuum pump, ion gauge			3BL fast ion loss probe	3CL movable Langmiur probe		3EL	
	3AL				3BB1		1DL fast pressure gauges		3FB
	3AB	FIR interf./polarim.			3BB2 glow probe & 2 filaments (5 c)	3CB equilib. magn. (120 MI)		3EB	

Electrical feedthroughs: tp=twisted pair, MI=mineral insulated cable, c= single conductor